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ON THE SIMULATION OF INVESTMENT BEHAVIOR*

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ON THE SIMULATION OF INVESTMENT BEHAVIOR

One of the few statements which can be made with any certainty about the endeavor called Operations Research is that it is primarily concerned with the analysis and improvement of decision procedures. Whether the subject of the inquiry is the location of a new retail establishment, the design of traffic patterns, or the scheduling of work orders in a plant, the objective is a set of procedures which will provide the user with an effective way of accomplishing the task at hand.

To design and develop such procedures it is customary to take a model of the system under consideration and deduce the requisite improvements from the model's behavior. As long as the model is adequate and testable--by adequate, I mean one that incorporates the relevant characteristics of the behaving system--its behavior can be explored under divers circumstances. Similarly, such improvements as are desired can be tested against the model's original behavior under controlled experimental conditions. In short, as long as the model is appropriate, improvements can be discovered by the application of procedures that are common to all branches of applied science.

To date little has been achieved by applying these methods to human decision behavior. Though many attempts have been made to delimit certain optimal strategies or decision procedures, e.g. game theory, and statistical decision theory, few have met with great empirical success. These difficulties have been caused by the models of human decision making that have been used--the models that are neither adequate nor testable. If none such existed there would be little that could be done to ameliorate the situation. But this is not the case. For research on the simulation of human decision behavior has led to the creation

of a number of testable models of decision-making behavior.[1] Being testable these models can be subjected to experimental investigation in the usual manner to discover which alteration in input as well as process produce the most desirable results. Accordingly, simulation models of human decision behavior provide the requisite basis for investigations into the improvement of decision-making behavior.

To explicate this approach the paper is concerned with examining some of the possibilities generated by applying experimental analysis to two simulation models. The models taken together encompass a considerable portion of what can be called investment behavior. The first represents the portfolio selection process of an institutional investor. It is capable of replicating the portfolio selections of a specific investor. The second represents the interaction that takes place between broker and trader in the Over-the-Counter security market. However, before investigation the methods by which improvements in these decision processes can be discovered, it is appropriate to have a brief description of each at hand.

The Investor[2]

This model was constructed to explain the portfolio selection process of an investor of trust funds. It represents the investment process as consisting

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[1] See for example, A. Newell and H.A. Simon, "The Simulation of Human Thought," in W. Dennis, (ed.) Current Trends in Psychological Theory, University of Pittsburgh Press, 1961, pp. 152-179; G.P.E. Clarkson and W.F. Pounds, "Theory and Method in the Exploration of Human Decision Behavior," Industrial Management Review, Vol. 5, 1963, pp. 17-27.

[2] For a complete description of this model see: G.P.E. Clarkson, Portfolio Selection: A Simulation of Trust Investment, Prentice-Hall, Inc., New Jersey, 1962.

of three main sections: (a) processes concerned with the analysis and selection of, from a basic set of stocks, a list of securities which are suitable for current purchasing, (b) processes which determine the investment policy of each account, and (c) the processes that perform the actual selection of securities for the individual portfolios. The basic information in the memory consists of data on particular economy and industry variables as well as all the data for a ten-year period on the relevant attributes of eighty companies and their securities.

Section (a) of the model uses these data to create various ratios and indices by which it can judge the relative performance and relative value of one company's stock against another. Expectations are also included in the data and are reduced to one scale so that patterns can be found and recognized. A pattern recognizing process is then employed to create the list of stocks that are suitable for current purchasing. This list is selected from the original set of stocks and its contents depend directly on the outputs of the relative performance, relative value, and expectational processes.

Section (b) consists of a mechansim that formulates an investment policy for a particular account by processing the data taken from the bank's records and the instrument setting up the trust, concerning the nature of the client or the trust. This mechanism is a discrimination net which associates certain patterns of data with specific investment policies.

In section (c) the portfolios are chosen by applying the selection mechaism associated with each investment policy to the list of companies produced by section (a). Concurrently, mechanisms are employed which decide how many shares to purchase and how to ensure that the portfolio is appropriately

diversified. The end result is a portfolio chosen for a particular account where the portfolio specifies the name of the security, the number of shares to purchase, the price per share at that time, and the total amount expended for each issue.

The model was tested for its ability to predict the actual behavior of the investor by requiring it to select a series of portfolios for an actual set of trust accounts. These accounts were processed both by the investor and the model during the first and third quarters of 1960. The portfolios chosen by the model compared very favorably with those chosen by the investor. As a further test, the decision processes by which the model generated its portfolios were compared with the investor's observed decision behavior. Though it is not possible to say that the model completely reproduces the observed behavior, the evidence from these tests strongly supports the hypothesis that the model explains a considerable portion of the observed investment behavior.[3/]

A model that describes and predicts one institutional investor's portfolio selection process is a long way from becoming a general theory of portfolio selection. But the evidence is there that models can be built that explain and predict, to a considerable level of detail, the decision processes of human investors.

[3/] An extensive analysis of the results obtained from these tests is presented in, ibid., Chapters 6 and 7.

The Trader[4/]

In the Over-the-Counter market a trader deals only with stock brokers or other traders. Under no circumstances is it possible for a private individual or institution to deal directly with a trader. The stock broker takes orders from investors and then telephones a trader to ascertain price. Since brokers charge a fee for this service, the cost per share to the ultimate purchaser differs somewhat from the price set by the trader. A trader usually maintains an interest in between fifteen and twenty stocks and in response to an inquiry will quote either a selling (asked) or a buying (bid) price on any one of these securities.[5/]

All trading activity is carried on over a telephone in very brief intervals of time. When asked for a price on a particular security, a trader responds, as a rule, with the bid and asked price on a hundred-share lot. Whether there will be an immediate transaction or not depends entirely upon the broker's reaction to the trader's quoted price. Since the broker can telephone any of the traders who are known to have an interest in this security, he is not dependent upon a single quote from one trader. However, as soon as a broker accepts a quoted price that is the market price in the particular security at the instant of time.

A decision is required of the trader each time a broker telephones to ask for a price. Since a trader must reply virtually immediately, one would not

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[4/] This model is described in detail in: R.A. Jenkins, "Professional Trader Price Quoting in the Over-the-Counter Market," unpublished Master's Thesis, Sloan School of Management, Massachusetts Institute of Technology, 1964.

[5/] The difference between asked and bid prices is what is known as the spread.

expect the pricing process to be unduly complex. Indeed, it turns out that the pricing process can be broken down into four main components which can be represented as follows:

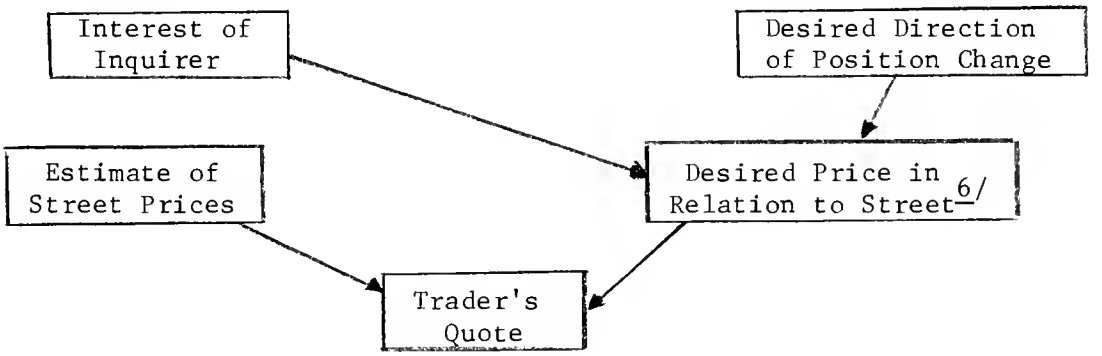

Figure 1

While each of these components is influenced by a number of other factors,[7] the decision process which takes place at the end of a telephone can be represented by the interaction of these four items. For example, a trader alters his quote depending upon the characteristics of the inquirer. Such factors as whether the inquirer is a buyer or seller, whether the orders from this person are usually large or small and whether he is a friendly[8] competitor or not affect the quote in a manner to be outlined below.

Concurrently, a trader knows whether he wants to increase or decrease his current long or short position in a particular stock. For, at all times the trader is aware of his current position as well as his estimate of the

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6/ "Street" is the name given by traders and brokers to the market as a whole.

7/ For a full description of the decision process see ibid., Chapter 3.

8/ A friendly competitor is one who does not take advantage of a bargain or poor quote.

position he would like to have. Since traders normally have a maximum amount of money that they can invest in any one security, their general impressions and attitudes toward the market, constrained by this limit, are what identify the position he would currently like to be in. Any discrepancy between the desired and actual position provides what has been labelled the "desired direction of position change".

The estimate of the (current market price) is normally derived by the simple process of listening to the broker's reply on the telephone. If a trader's quote is accepted then he is either right on or a little low (on asked price), right on or a little above (on bid price) the current market. Conversely, if no transaction is effected, his asked price is a bit high and his bid price is a bit low. If, for some reason, the stock has not been traded for awhile, a trader can obtain an estimate of the current price by telephoning a competitor. But if the stock is being actively traded, each trader will have a fairly accurate estimate of the street price. Given this estimate and any desired change in position, the quoted price can be directly determined.

While the actual increments, e.g. 1/8, 1/4, 1/8, etc., may vary with different securities[9/] the price setting decision process can be represented by the following table:

[9/] See ibid., Chapters 3 and 4 for a detailed discussion of the variation in spread--in particular the relation of the size of the spread to volume and price.

Inquirer and His Interest	Desired Direction of Position Change	Desired Price Relation to Street	
		Bid Price	Asked Price
Retail Buyer	longer	1/8 above street	1/4 to 1/2 above street
	indifferent	equal street	1/8 above street
	shorter	1/4 below street	equal street
Retail Seller	longer	equal street	1/4 above street
	indifferent	1/8 below street	equal street
	shorter	1/4 to 1/2 below street	1/8 below street
Friendly Competitor (Interest unknown)	longer	equal street	1/8 above street
	indifferent	equal street	equal street
	shorter	1/8 below street	equal street
Enemy Competitor (Interest unknown)	longer	much lower than street	much higher than street
	indifferent		
	shorter		

Table 1

Table 1 describes the components of the price quoting decision process in sufficient detail to permit some of them to be subjected to test. Further, from the evidence presented in the study, these decision processes are sufficient to account for a substantial proportion of the observed changes in traders' prices for a number of securities.[10/] Consequently, it can be accepted, for the moment, as a detailed representation of the price setting decision process.

[10/] See ibid., Chapters 4 and 5.

Empirical Analysis of the Investment Models

Given two such models of investment behavior it is reasonable to inquire into the procedures by which the decision processes themselves can be examined for improvements. For neither are stated in the more usual mathematical form nor have they properties that are consistent with the derivation of optimal strategies. The direct approach is to discover improvements in process by subjecting such models to experimental analysis.

For example, consider the model of the trader's price-setting process in relation to the various statistical investigations that have been conducted on stock price time series.[11/] These latter investigations have led to the conclusion that stock price behavior as viewed from certain time series is consistent with a random walk between reflecting barrier hypothesis. However, if the model presented here can be accepted, for the moment, changes in price over time are a consequence of the interactions between broker and trader. Consequently, it would appear that more could be learned about the relevance of the statistical characteristics of such time series by an experimental examination of the behavioral processes by which they are generated. For an analysis of the price-setting mechanism may well identify the principal factors which affect the movement of prices over time.

Consider the case of an infrequently traded security. In particular, let us restrict our attention to one which is held by a single trader. Here the price time series for this security is a direct result of the interaction between

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11/ An excellent survey of these researches is available in: P.A. Coutner, (ed.), The Random Character of Stock Market Prices, M.I.T. Press, Cambridge, 1964.

one trader and one or more brokers. Both of their decision procedures can be described in detail. And it is clearly possible to construct a specific, testable model of this market behavior. If the model is provided with the requisite information the end result will be a series of prices. This sequence of prices will, if the model is properly constructed, correspond to an actual, observable time series. Since the generated sequence of prices is a perfectly respectable time series, it can be submitted to the same statistical analyses as are employed in the above noted researches on stock prices. But, and this is the important point, whatever inferences are drawn from such statistical analyses, the model provides the mechanism by which these statistical characteristics are produced. Indeed, if it can be shown that certain decision processes, on the part of both broker and trader, lead invariably to the generation of time series with particular statistical characteristics, then a basis would have been established from which inferences could be made from statistical properties back to the underlying decision procedures. If, as may well be the case, different sets of decision processes lead to time series with significantly different characteristics, then these characteristics with their corresponding decision processes could be grouped into separate classes.

While these suppositions may appear somewhat hopeful, and may be rejected out of hand as requiring far too much effort to investigate, permit me to remind one and all that they are perfectly straightforward propositions which can readily be subjected to empirical analysis. In addition, whether or not they turn out to be corroborated, the process of subjecting them to test would not be as involved as it may first seem. For, given a model of the price-setting process its behavior can be assessed under a variety of initial conditions and environ-

ments. If the time series so produced vary significantly in their characteristics, then it would follow that these properties can be classified by decision procedures as well as by environmental conditions. Concurrently, by examining price-setting decision processes in several markets it would also be possible, given some differences in these processes, to identify the effect these differences have on the behavior of prices over time. In short, such research would lead to a more detailed understanding of market behavior as well as an explication of the origins of specific time series and their statistical characteristics.

One consequence of such investigations would be the ability to discover, on empirical grounds, answers to such questions as: (1) How should trading in securities markets be managed? (2) How should traders behave in order to improve their performance?

Consider the problem posed by question 1. First one has to establish the criteria by which a market's performance is to be adjudged. A possible criterion is that under all possible environmental conditions the trading process must be such as to achieve an orderly market. One way of describing an orderly market is in terms of the properties of its time series. If certain classes of time series are considered to satisfy the relevant criteria, it would be necessary to prescribe a set of decision mechanisms which would produce the requisite series. These mechanisms would, no doubt, have to include some safety devices to accommodate the occurrence of a large run on the system, but a solution can be discovered by an experimental analysis of the properties of alternative decision processes.

Question 2 can be resolved in a similar manner. For, if the primary concern is to ensure that the security markets serve investors and not just traders and brokers, one is searching for improvements in trader performance that will enhance the behavior of the market as a whole. Once again specific criteria must be introduced and accepted before proposed improvements can be critically examined. However, as soon as appropriate standards are devised, better procedures can be discovered, evaluated, and adopted.

The same remarks apply with equal force to the portfolio selection process itself. For one of the main concerns in portfolio selection is to be able to choose good portfolios under all possible market conditions. Effort spent on the gathering of more accurate information on a company's or industry's behavior clearly reduces some of the uncertainty. But, it is my opinion that effort spent on discovering better selection techniques will generate larger payoffs. For with a model of a price-setting mechanism available one can simulate a market environment. Thus controlled experiments can now be run on the portfolio selection process under varying market conditions.

For example, in order to judge the quality of a portfolio, criteria need to be established which reflect the desirable properties of various types of portfolios. Given such criteria portfolio selection procedures can immediately be tested against actual market data. For processes and/or components of processes can be altered, one at a time, and the statistical significance of the effects on the securities selected noted. Once an effective set of procedures have been discovered in this manner, this decision process can now be tested using the model of the price-setting process against a range of simulated environments to determine its behavior under such changing conditions. In

brief, the existence of testable models of investment behavior immediately provide us with the capability of discovering effective investment decision processes by the repeated application of controlled experimental analysis.

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